Towards Making a Modern Stradivarius

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Abstract

The quality of music is generally dependent on the quality of the instrument used. Thus professional instruments are crafted to exacting standards. One of the most versatile instruments in use today, played across several schools of music, is the violin. The best violins were made in Cremona, Italy in the 17th and 18th Centuries by Stradivari and Guarneri. Their violins are generally priced at millions of dollars. Mere physical replication of these violins still cannot match the richness of tone of the Cremona violins. With improving technology, there has been an impetus in research in the chemistry of wood and varnishes used in violin making and the treatment of the materials to do so. This paper explores current research in violin technology.

1. Introduction

The relationship between art and science is fundamental: art is the expression of human sensibility and science provides the framework and the tools, by careful examination, on which all great art must rest. Art and science have always been interdependent.

Of the arts, music is one of man's supreme achievements – it has no language, no boundaries, and it can move the whole of humanity regardless of race, gender or nationality in the same manner. Of all the musical instruments, those of the string family are the most popular. The sound of the violin is considered especially wonderful as its sound is the closest to that of the human voice (at least in the Western Classical repertoire). Very little sound in a violin is produced by bowing its strings. The body of the violin has many resonant frequencies which further amplify these sounds, transmitted by the bridge (Hsieh, 2004)

As the quality of the sound is subjective to the listener, to make its analysis more objective, it is often graphically observed in a loudness curve, where the relationship between the amplitude (loudness) and the frequency is plotted. There are four peaks associated with these curves at four different frequency ranges: The Helmholtz resonance (at around 275 Hz), main body resonance (when the front and the back plates resonate simultaneously), nasal range (between 1300-1600 Hz) and brilliance range (higher than 1600 Hz). This curve can be analyzed using the Fast Fourier Transform (FFT) (Spycher, 2007). Good violins have large amplitudes at low frequencies and small amplitudes at high frequencies (Meinel, 1957).

The greatest violins in existence today are those that were made in Cremona, Italy, in the 17th and 18th centuries. Their brilliant tone and colour have not only made them prized and valuable possessions, but have also inspired researchers to try and replicate their sound. Indeed, they are so valuable that it has been proposed that their repair work should be preceded by CT scans (Sir and Waddle, 1997).

Today, even with world-class craftsmen, tools and mechanization, not to mention the exact physical replication of Cremona violins, it has not been possible to match the Strad. This quest initially consisted of tweaking the design and plate tuning, but were unable to replicate the Cremona masters' sound quality. This shifted interest in the material properties of the violin instead (Nagyvary, 2008).

2. Making the Violin

The violin is a bowed string instrument that was developed around the 16th century. It is a complex instrument consisting of around 70 parts, the construction of which is often tricky, and its acoustics peculiar, such as a "wolf note" at certain frequencies causing the body of the instrument to vibrate in an unusual manner (Raman, 1916). Making a quality violin is therefore a very skillful task.

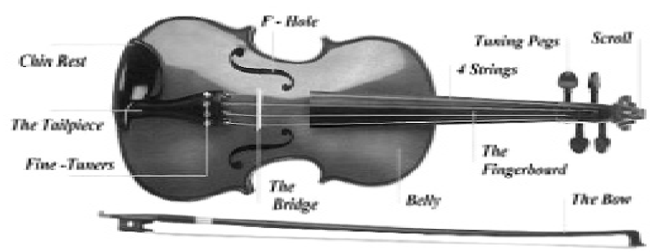

Figure 1 : The Visible Components in a Finished Violin are Labeled in

Traditionally, the sound post, top and back of the violin is made using spruce, the scroll, bridge and back-plate using curly maple, and the fingerboard using ebony.

The lowest part of the trunk is generally used in violin making. The procedure for selecting materials for making a violin are usually crude. The wood used for sound boards is selected by looking for straight grain, low density and bending tests (Spycher, 2007).

The criteria for selection includes checking the annual ring width containing three rings within 1 cm (Hrivnak, 1996), approximately equidistant and with grain parallel to the axis of the trunk. This is because wood is composed of cellulose, and bound by lignin and hemicellulose, also binding adjacent cells. This causes the longest dimension of the cell to grow in parallel to the axis of the trunk, thus giving it the greatest tensile strength. The thickness of the rings and their uniformity are also considered (Horcin and Gubriansky, 2005; Hsieh, 2004).

3. Methods of Analysis

Several methods of analysis are used in evaluating the composition and structure of violins, their components and varnishes. von Bohlen (2009) has described a technique for surface analysis of violins using Total X-ray Spectrometry, μPIXE has been used for the elemental analysis of varnishes in historical violins (von Bohlen et al., 2006). Backscattered Electron (BSE) imaging has been used for the determination of the mineral composition of violin wood (Nagyvary, 2009). The most important methods are listed below:

3.1 Energy Dispersive X-Ray Spectroscopy

Energy dispersive X-ray spectroscopy is widely used in the analysis of historical stringed instruments. Energy dispersive X-ray fluorescence (EDXRF) technique has been used for varnish analysis and is especially useful since it does not require sampling, leaving the violin intact. Direct analysis can be performed and the elemental analysis can give an idea of the pigments used (Jean-Philippe Echard, 2004).

3.2 Infra-red Spectrometry

Infra-red spectrometry can be used for elemental analysis of violin varnishes to determine the organic and inorganic molecules of pigments and binding media (von Bolhen et al, 2007).

3.3 Scanning Electron Microscopy

The surface of violins is often analyzed using scanning electron microscopy (SEM). SEM of a Stradivarius violin has revealed an application of volcanic ash between the wood and the varnish (Barlow et al, 1988).

3.4 Nuclear Magnetic Resonance

This technique is used to analyze the composition of wood. It was used to examine the organic matter composition in the wood of Cremona violins, to determine if they had been chemically treated. Interpretation of NMR spectra for violin analysis was described by Kolodziejski et al., in 1982 and Kosikova et al., in 1999 (Nagyvary, 2006).

4. The Cremona Violins

Research on Cremona violins has thrown up many possibilities of the cause of their superior sound (Wright, 2004). One such effort by Nagyvary indicated that the rich sound of the period may be attributed to the degradation of wood fungi, causing greater penetration of varnish, as evidenced from the large amounts of minerals like calcite and gypsum, commonly used in the varnishes of the period. Later research by him showed that chemical preservatives could have led to the degradation of wood polymers, and that the wood may have actually been stored in brackish water, leading to degradation of hemicellulose.

Another study attributes the rich sound of the "Golden period" of violin making to reduced sunspot activity occurring between 1645 and 1715, known as the Maunder Minimum, causing cooler summers, leading to slower, more even growth of wood (Burkle and Grissino-Mayer, 2007).

Another aspect of research focuses on the varnish composition of Cremona violins, though this theory has been criticized for two reasons: 1. Varnishes generally have damping effect on vibrations. 2. These violins have been subjected to repair as well as recoating in the last 150 years (Hsieh, 2004).

5. Towards the New Strad

As researchers hunt for the "Secret of the Strad", luthiers have tried to incorporate research data and replicate wood constitution in making this dream instrument (Nagyvary, 1988). Nagyvary constructed violins from wood salvaged from the bottom of a lake, infused with a wealth of minerals, and producing sounds similar to those of a Strad, as pointed out by a blind study with 400 judges.

Spycher (2008) subjected wood of Norway spruce (Picea abies) and sycamore (Acer pseudoplantus) to wood-decay fungi to increase the modulus of elasticity and reduce the density of the wood, making it more uniform. This replicated the wood growth in a cold climate as was present during the 18th century during the Maunder Minimum. This showed a marked improvement in resonance wood quality for violin making.

6. Conclusion

Cremona violins possess a mystique for every violin player or violin lover in existence. The quest for replicating these violins has been going on since the last 150 years, though, it may be only toady that we have the resources to properly analyze these masterpieces. Even after dedicated research to this, the Stradivarius and Guarnerius flummox researchers. While everyone wants to replicate the sound quality of these exquisite instruments, once it does succeed, the romance will remain.

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